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MESOSCALE ASSESSMENTS OF CLOUD AND RAINFALL

OVER THE BRITISH ISLES

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ERTS Follow-on Programme Study No. 2962A

(E76-10095) MESOSCALE ASSESSMENTS OF CLOUD AND RAINFAIL OVER THE BRITISH ISLES (Department of Industry) 29 p HC \$4.00 N75-16518

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Quarterly Report

by

M.Sc., Ph.D., F.R.G.S., F.R.Met.S.. F.B.I.S.,

and

Colin K. Grant

2962A

Supported by the U.K. Department of Industry, Monsanto House, 10-18, Victoria Street, London, SW1H ONQ

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# MESOSCALE ASSESSMENTS OF CLOUD AND RAINFALL

## OVER THE BRITISH ISLES

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# Quarterly Report

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M.Sc., Ph.D., F.R.G.S., F.R.Met.S., F.B.I.S.,

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Supported by the U.K. Department of Industry, Monsanto House, 10-18, Victoria Street, London, SW1H ONQ

## I. INTRODUCTION

This investigation began as a proposal for studies of cloud and associated rainfall over south-western England and the western sea approaches within the limits defined by latitudes 49° and 55°N and longitudes 0° and 20°W, associated with other proposals from the University of Bristol related to the Sabrina Project. This is an inter-disciplinary study of the estuary of the River Severn and its environs, considering many aspects of its natural science independent of, and affected by, the activities of man. Since the related proposals dealt with terrestrial and marine phenomena and their distributions through space and time, a complementary programme of work was designed to examine atmospheric variables which might have a bearing upon them.

In the event, the related proposals were not accepted by N.A.S.A., leaving the proposed study of cloud and rainfall to stand alone as an independent investigation. Modifications were clearly necessary to the study plan. Of these, the most fundamental was the re-drawing of the area involved. Cut free from the need to focus attention on south-western England, it was decided to include the whole of the British Isles in the revised investigation so that resulted of more general significance to the United Kingdom of Great Britain and Northern Ireland and the Irish Republic might be obtained. This had less of an effect upon the required photo-coverage than at first it might be thought likely to have had. In the original plan a rainfall forecasting component was included, for which data coverage well beyond the coastline of south-western England would have been required (cf. the rainfall forecasting method described by Barrett (1973) based on weather satellite data). Negotiations with N.A.S.A. on new limits for the revised study region resulted in the allotment of the co-ordinates listed in Table 1.

TABLE 1

Effective co-ordinates for the revised study plan (clockwise order)

Corner	Latitude	Longitude
North-west	60°00'N	12°30'W
North-east	60°00'N	2°30'E
South-east	49°00'N	2°30'E
South-west	49°00' N	12°30'W

This conclusion is advantageous from the point of view of the cloud analyses planned for the revised study, but very disadvantageous from that of examining cloud/rainfall/river flow relationships, excepting possibly on a rather local basis.

One further type of problem must be outlined owing to its considerable and continuing - influence on the study plan. No suggestion was made before Landsat 2 went into operation that the data coverage for the region indicated by the co-ordinates in Table 1 would be other than that described by N.A.S.A. in its Data Profile (Attachment B) to the Principal Investigator, namely from March 1975 - February 1976 for up to and including 100% cloud cover. Although it was appreciated that the "best efforts to provide the Principal Investigator with the ERTS data described in the data profile" (N.A.S.A., 1974) recognised that some short-fall might occur, especially if technical problems were encountered, so far reality has proved to be unexpectedly disappointing. By the time of writing (December 8th, 1975) a total of 180 frames have been received, covering the period from the launching of Landsat 2 on 22 January, 1975 to the end of July. This compares poorly with the anticipated maximum number of frames which might have been expected had there been a full and complete coverage in space and time, which we estimate to be about 560. This actual coverage does not compare well with that in some other regions (e.g. U.S.A. and southern Canada; the Middle East; eastern Siberia and China), and has had implications for the structuring of our programme of work, especially insofar as the order of work to be done, the acquisition of in situ ("ground truth") data, and the identification of realistic goals are concerned. Some discussion of these points is inherent in the sections that follow.

#### II. TECHNIQUES

For the present, attention is being focussed on the first of the detailed objectives outlined in the Statement of Work (Attachment A, N.A.S.A., 1974).

This seeks:

"To develop a unifying paradigm of cloud statistics from Landsat, Noaa and conventional sources for encyclopaedic purposes, and for use in the planning of future programmes of Earth Resources studies from aircraft and satellites". Given that some time elapses before weather satellite image data are available from the U.S.A. in a form suitable for easy use (as computer-rectified, brightness-normalized products) our immediate concern is with the acquisition of appropriate conventional weather observations, and the development of means of comparison between them and the Landsat images. Table 2 lists the frames received by early December. Fig.1(a - g) illustrates their coverage by individual Landsat cycles. It is clear that this is both fragmentary and variable from cycle to cycle. Although this is not necessarily a significant problem so far as the compilation of worthwhile populations of cloud statistics on a non-location specific basis is concerned, the broken coverage through space and time may limit the possibility of other than case studies for specific areas.

Table 2 also indicates the time of Landsat imagery for each frame. The range of times across the rather large expanse of the study region is from 10.00 - 11.30 G.M.T. Fig. 2 illustrates the detailed distribution of the imagery through time. In view of the large area involved, and the uncertainty of obtaining Landsat cover on specified dates, the collection of ground truth information has been based on existing and operational data sources. The Meteorological Office of the United Kingdom maintains 98 weather observing stations in the British Isles (with a further 12 in the Republic of Ireland) of which weather records are compiled on an hourly basis and their geographic distribution is illustrated by Fig. 3. It is from these that our basic ground truth file is being compiled. It is recognised that some time difference will occur usually between the local time of Landsat imaging and the time of weather observation. This difference ranges from about - 50 mins. When the 1100 G.M.T. conventional observations are invoked.

The Meteorological Office was consulted on the possibility of their Observers making additional observations of the more significant parameters (cloud type and amount, visibility and rainfall) or rearranging their observing schedules on pre-determined days to afford a better coincidence with the time of Landsat imagery. Such possibilities were ruled out by the Meteorological Office

TABLE 2

LANDSAT 2 COVERAGE OF THE BRITISH ISLES
TABULATION OF INDIVIDUAL FRAMES

DAY	DATE	ORBIT. No.	FRAM	E Nos	TIME .	CO-ORDS OF	CENTRE
LAUNCH)	(1975)		40	5	H: M: 5	LATITUDE	LONGITUDE
2068	31 MARCH	0944	052	031	10:49:10	N 60:07	W 003 : 20
			011	032	10:49:40	N 58:44	W 004 : 15
			053	033	. 43.40	14 30 . 47	
			054	075	10:50:00	N57:21	W 005 : 1
4			055	076	10:50:30	N55 : 57	w 006:0
		4	014	035	10:50:50	N54 : 33	w006:5:
	-		056	036	10. 30.30	11.04.33	w 006. s.
	•		057	078	10:51:20	N 53:09	W007:4
		.,	016	079	10: 51:40	N51:44	w008:2
			017	038	101 50.15		(1)000110
			059	030	10: 52:10	N 50: 20	W009:0
			060	081	10: 52:30	N 48:55	W009:4
			165	180			
2069	I APRIL	0958	195	210	10:55:00	N 60:09	W004:1
			166	211	10: 55 : 20	N 58: 46	W 005:4
	·		196	182			
		and the same of the same	168	183	10:55:50	N57:23	W 006: 4
			198	213	10:56:10	N55:59	W007:3
			169	184	10:56:40	N54: 35	W008:5
			170	185			
	1		171	218	10:57:00	N 53 : 11	W 009:0
		7	201	216	10: 57:30	N51:46	W 009:4
The same of the sa			173	198	10:57:50	N 50: 22	W010:3
	and a service and the service districts and a service and	A Market of the states bearing to the first out of the state of	174	199			
			224	249	10:58:20	N48:57	M 011:0
2020	2.000	0022	062	082	11 1 0011 0	N 60 : 07	W006:1
2070	2 APRIL	0972	102	083	11:00:40		1.
			103	(23	11:01:10	N 58 : 45	W 007:
			104	124	11: 01:30	N57: 21	W 008:0
			065	. 083	11: 02:00	NS5: 57	w 008:5
			105	086	11. 02.00		
	RIGINAL PAGE I	\$	106	126	11:02:20	N54:34	W009:4
· · · · · · · · · · · · · · · · · · ·	COR QUALITY		. 107	127	11: 02:50	N53:09	W010:3
			068	023			W011:1
			145	138	11:03:10		
			207	238	11:03:40	N50:20	MOII: 5
	•		208	239	11:04:0/	N 48: 55	W012:3

DAY	DATE	ORBIT NO		TIME	CO-ORDS	OF CENTRE
LAUNCH)	(1975)		4 57	H: M: S	LATITUDE	LONGITUDE
2121	23 MAY	1682	018 042	10: 45:40	NS1: 31.	W007:10
"	"	,	067 091	10:46:10	NS0:07	WOOT:50
	<b>N</b>		063 092	10:41:30	N48:43	w008:28
2122	24 MAY	1697	134 146 135 147	10:49:20	Ns8:29	W004:36
		•	151 . 621	10:49:50	N57:06	MOOS:30
<u>.</u> u	4		136 148 160 172 137 149	10: 50:10	NSS:43	mo06:50
			161 173	10:50:40	NS4:19	80:500w
	•		162 174	10:51:00	NS2:55	woo7:53
	**		163 AS	10:51:30	N21:30	woo8:36
4	** ,		164 176	10:51:50	NS0:06	W009:16
			165 177	10:52:20	N48:41	₩009:55
					5-0-1	The second second second
2126	28 MAY	1753	138 164	11:12:00	N59:48	w009:27
		۸۱.	197 226	11:12:30	N58:26	W010: 25
	4		198 227	11:12:50	N57:02	mo11:18
			199 228	11:13:20	NSS: 40	MOIS: 09
	4		200 229	11:13:40	N54:17	W012:56
u	4		201 230	11:14:10	N52:52	W013:41
2128	30 MAY	1381	051 09(	11:23:30	NS9: 45	W 012:23
			135 135	11:24:00	N28:55	W013:20
				•		
2131	2 JUNE	1822	055 078	10:00:30	N 49:57	E 003:2
•			056 079	10:00:50	N 48:33	E002:50
					2. 4.	
2132	3 JUNE	1836	195 218 241 264 196 219	10:05:00	N54:07	E004:08
•	; <b>.</b> ,	as an experience of the first of	196 219 242 265 197 220		N52:43	E003:24
			243 266		N51: 19	E002:42

					30		
DAY	DATE	ORBIT No.	Frame 1	'	TIME	CO-ORDS O	F CENTRE
LAUNCH)	(1975)		6	3	H : M : S	LATITUDE	LONGITUDE
2140	11 JUNE	1948	033	021	10:51:20	N52:53	no:800m
,	ч .		039 .	056	10: 51: 50	N51:29	mo08:43
4			040	023	10:52:10	NSO: 05	Es: 600 W.
		•	041	058	10: 52: 40	N48: 40	W010:01
		4	,		. / /		
2142	13 JUNE	1976	099	116	11:02:30	NS4: 15	W010:12
4	٠, ,		100	083	11:02:50	NS2:51	F2:010W
4	<b>4</b>		101	118	11: 03:20	N21:57	wo11:39
u		•	102	119	11: 03: 40	N20:03	MO15: 10
		***	103	120	11:04:10	N48:38.	W012:57
		and the contract of the contract of	05/	0/0			·
2145	16 JUNE	2018	086 087	0002	11:18:00	N59:45	mo11:03
120000		•	081	093	11:18:30	N28:53	MO12:00
	4		08.5	070	11: 18:50	NS7:00	mo12:54
AND ADDRESS MANY AND ASSESSMENT AND ASSESSMENT ASSESSME	"		083	035	11: 19:20	NS5:37	mo13:44
2150	21 JUNE	.2087	103	138	11:05:30	N52:54	E003:27
. "		\ '	154	139		NZ1: 30	E002:45
						A DESCRIPTION OF THE PERSON NAMED OF THE PERSO	
2151	22 JUNE	2101	012	060		N50:06	E000:37
						- 14 - 14 - 14 - 14 - 14 - 14 - 14 - 14	
2152	23 JUNE	2115	005	110	10:15:20	N28:56	E003:49
	4		076	111	10:15:50	N57:03	E002:55
	4 / 1		008	112	10:16:10	NSS: 40	E002:05
" ORIGI			038	113	10:16:40	N54:16	E001:18
" OF PO	VAL PAGE IS		079	114	10:17:00	N 52:52	E000:33
	VAL PAGE IS R QUALITY	4	081	116	10:17:50	N50:04	w000:50
	•		082	117		N48:39	W001:28

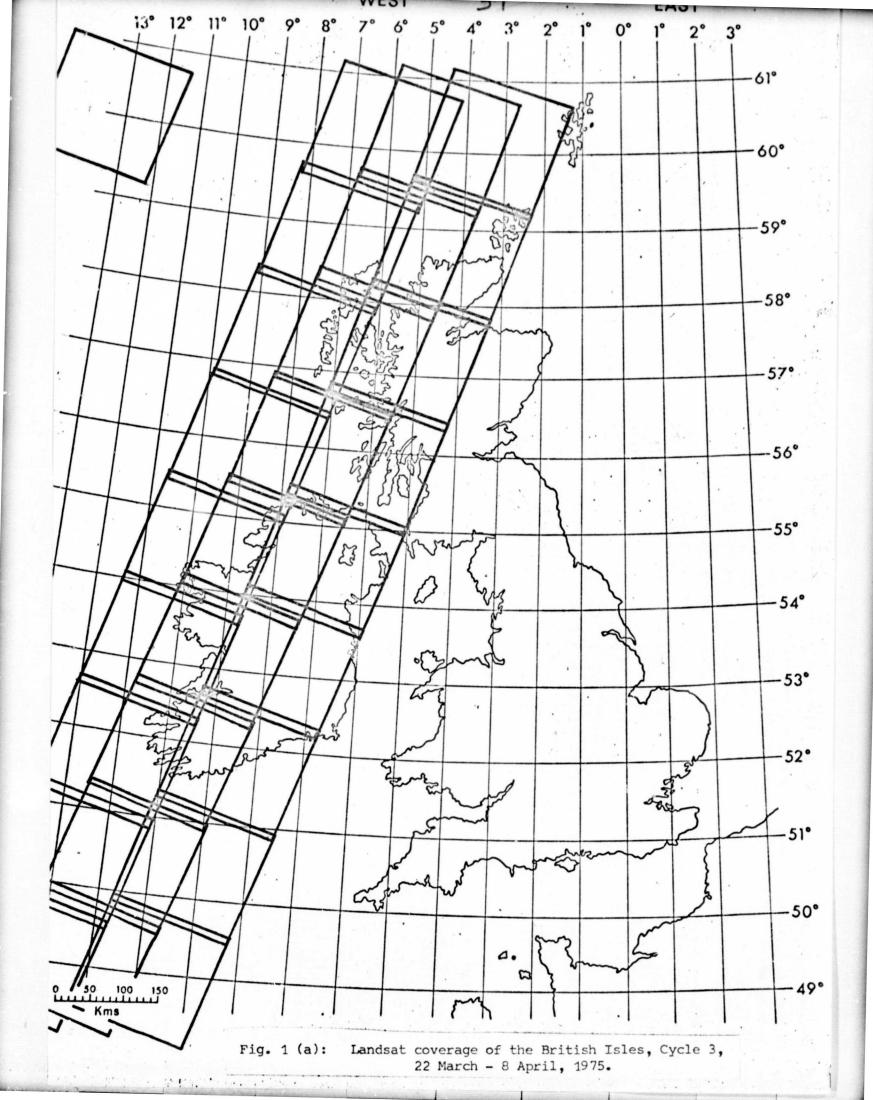
DAY	DATE	ORBIT No.	FRAME Nos.	TIME	CO-ORDS OF	CENTRE
LAUNCH)	(1975)		6 7	H: M: 5	LATITUDE	LONGITUDE
2173	14 JULY	2408	195 214	10:32:50	NS7:19	W001:13
"	4	4	196 215	10:33:10	N55:55	M005:01
			197 216	10: 33:40	N54:32	W002:52
4	١,		198 217	10:34:00	N53:07	MO03:37
	4		199 218	10:34:30	N51:43	MOOH: 20
4	"		200 219	10:34:50	NSO: 19	W005:01
<b>L</b> 1	3 4 4		201 .220	10:35:20	N48:54	W005:40
2174	15 JULY	2422	134 123 036 112		N.60:03	W000:4
	·		135 154		NS8:41	W001:4
	4		136 (55	10:38:30	N57: 17	m 005:3
3 <b>u</b>		4	137 156	.10:38:50	NS5:54	W003:3
	,		(33) (58)	10:39:40	N 23:06	woos:0
	4	4	140 159	The same of the sa	NS1:41	W005:4
		,	141 160	10:40:30	N50: 17	W006:25
•	6		145 161		N48:52	W007:0
			011 037			
2175	16 JULY	2436	063 089	10:43:20	N60:07	moos:11
	4		064 090	10:43:50	NS8:45	M003:11
4	4		065 091	10:44:10	N57:21	m004:0
4			066 092	10:44:40	NSS:57	W 004:56
4	[ · · ·		067 093	10:45:00	NS4:34	woos:4
		, , ,	08 094	10:45:30	N23:10	W006:2
			057 084		N50:21	W007:5
2176	17 JULY	2450	013 042	10:49:10	N60:05	W003:3
	١	١. ،	014 043	10:49:30	NS8:43	W004:3
4	4	4	073 102	10:50:00	NS7: 19	woos: 3
4			074 103		NSS. SE	woo6:22

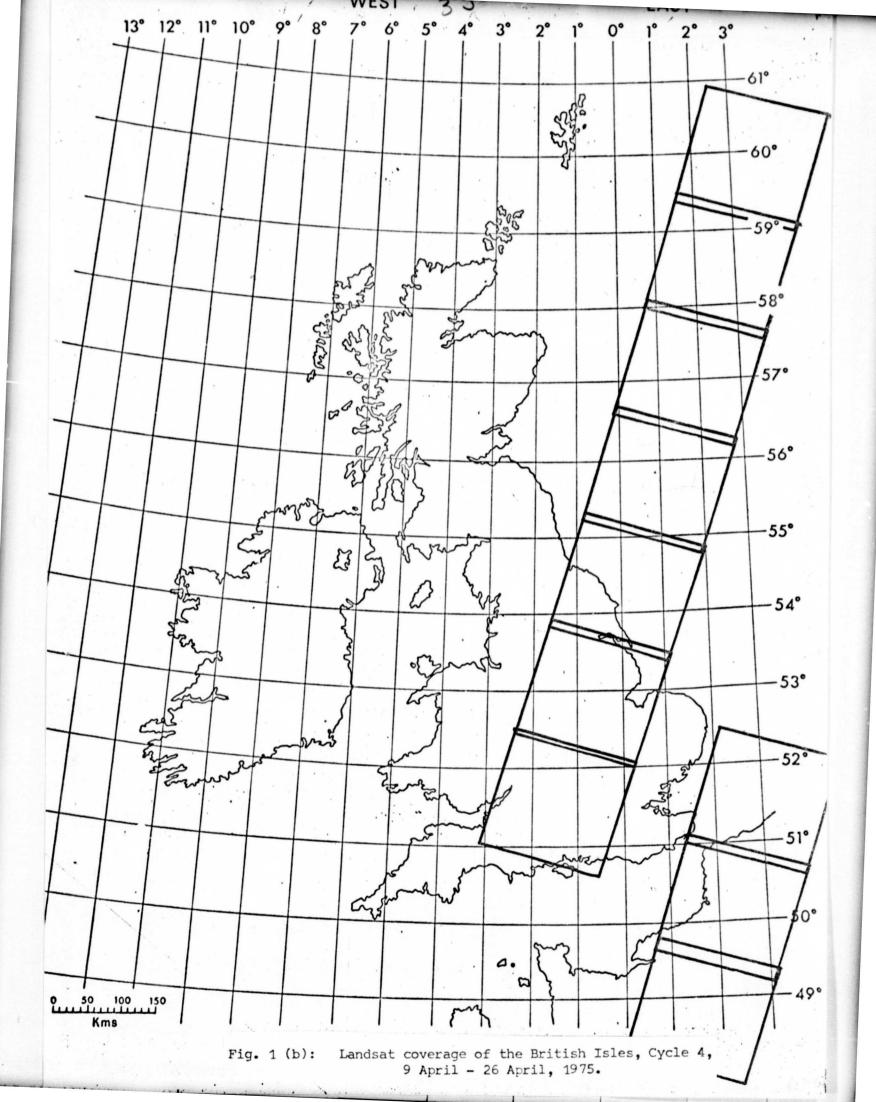
DAY	DATE	ORBIT No.	FRAME	man and a second	TIME	0 2090-00	F CENTRE
EMCE LAUNCH)	(1975)		34	57	H : M : 5	LATITUDE	LONGITUDE
2071	3 APRIL	0986		067	11 1 09120	N 50:19	W 013 : 25
2075	7 APRIL	1042	115	160	11 : 29:20	N 60:06	W013:33
2078	10 APRIL	1083	031	016	10:05:50	NS1:35	E002:50
			032	047	10:06:20	NSO: 10	E002:05
			033	048	10:06:40	N48:46	E001:31
			209	02.9			
2081	13 APRIL	1128	049	069	10:20:40	NS9:52	E003:28
, · ·		4	050	070	10:21:00	NS8: 29	E002:30
. •		National Action of the Assessment of the Assessm	051	071	70: 21: 30	N57:06	E001:36
	• 12		052	033	10:21:50	NSS:42	€000:45
			053	033	10: 22:20	N54:18	w000:03
			054	034	10:22:40	NS2:53	wooo: 4.
			oss	0.32	10:23:10	NS1:29	W001:31
			-X		in the second of		
2120	22 MAY	1669	173	191	10:37:20	N60:10	m 008:3
	••	",	134	192	10:37:50	N58:48	W001:3
٠	4		132	157	10: 38: 10	N.57:25	w002:2
			176	194	10:38:40	N56:01	m003:11
		•	177	195	10: 39:00	NS4: 37	W004:0
	11	1.1. <b>4</b> 7	178	136	10:39:30	N53:13	W004:5
			133	197	10:39:50	NS1:48	W005:34
••		, 4	180	188	10:40:20	N50: 25	W006:11
	•		181	165	10:40:40	N49:01	W006:5
				(121)			\
2121	23 MAY	1682	063	039	10:44:30	NS5: 43	W004:5
•	••		016 .	088		NS4: 19	W005:4
			065	041	10:45:20	N52 . 55	W006:

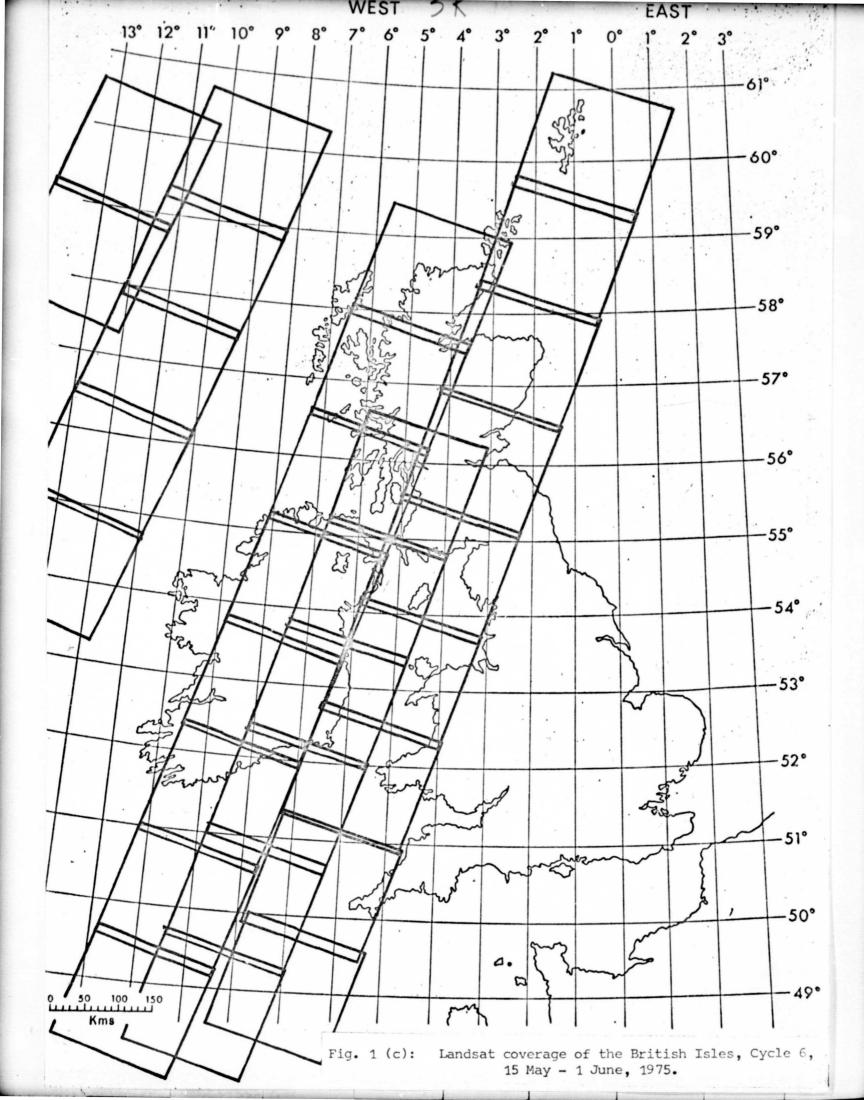
DAY	DATE	ORBIT No.	FRAME Nos	TIME	CO-ORDS OF CENTRE			
SINCE LAUNCH)	(1975)	01.011.10.	40	H : M : S	LATITUDE	LONGITUDE		
2132	3 JUNE	1836	198 221 244 267 199 222	10:06:10	N49:55	E002:07		
			199 222 245 268	10:06:40	N48:30	E001: 23		
2133	4 JUNE	1850	one 065	10:11:30	NSI: 19	€001:16		
"	"		012 029	10:12:00	N49:55	E000:37		
	<b>\</b>		013 030	The second secon	N48:31	w000:02		
*	30 S. C. C. S. S. S. S. C.		,	4				
2135	6 JUNE	1878	003	10:23:30	N49:59	W002:15		
			064 090	10:23:50	N48:34	w002:5		
	18 10 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		001 028					
2137	8 JUNE	1906	065 082	10:34:10	N52: 47	W003:41		
•			056 083	10:34:30	N21:53	W 004: 21		
	, M		057 054	10:35:00	N49:59	W005:0		
			058 085		N48:34	W005:4		
	*	*	014 041		NS6:58	W 001:2		
			068 095			W 003: 0		
			r69 096	10:55.40	N34. 11	- 003.0		
2139	10 JUNE	1934	149 171	10:43:30	NS9: 40	W002:3		
4	u		194 216	10:44:00	NS8: 17	W 003: 2		
			195 . 513	10:44: ??	, ?	1 3 3		
4			152 131 196 218	10: 44: 50	NSS: 30	woos:0		
	`N		197 219	10:45:10	NS4:07	woos: s.		
	*****		199 22	10:46:30	N49:54	W008:0		
			200 27	1	N48:30	C:3000		
		ļ	001 018		1			
2140	11 JUNE	1948	035 05	10:50:10	N 57:04	w 005:3		
·	<b>\</b>		036 05	10:50:30		W 006: 2		
		1	037 050		N54:17	W 007:1		

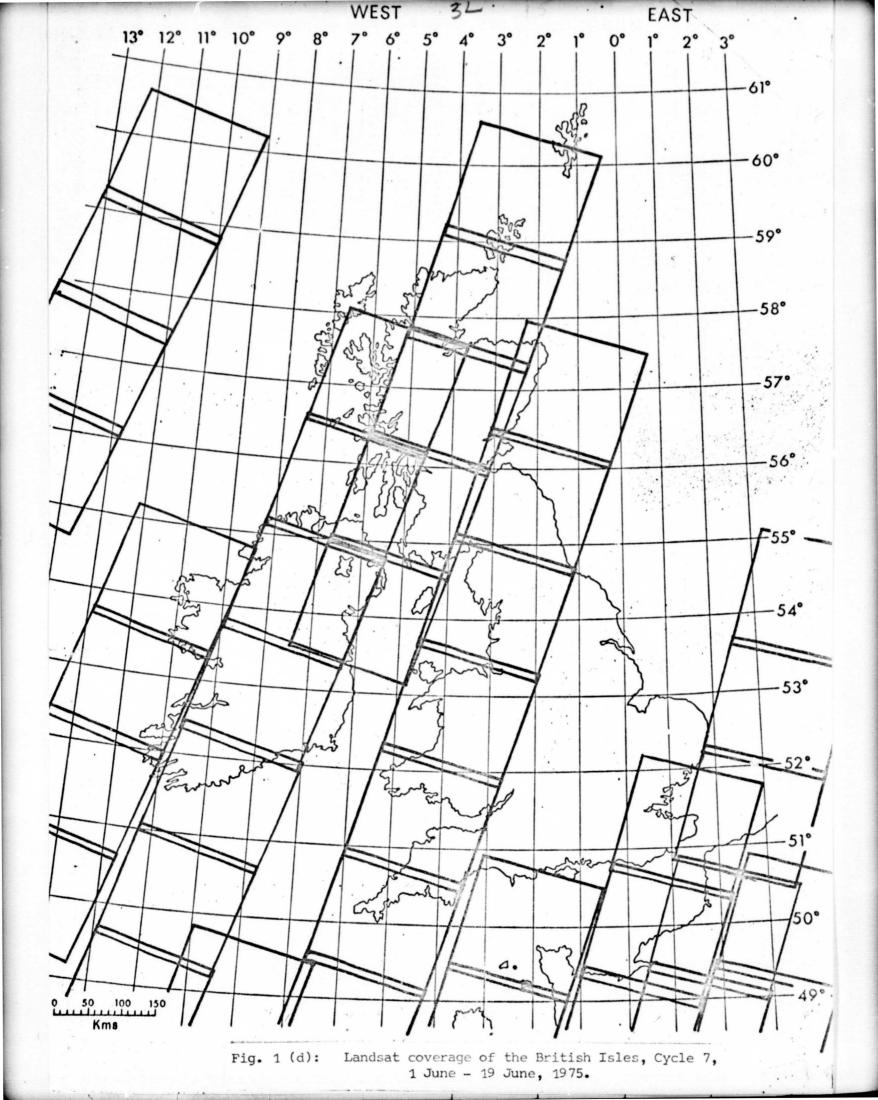
		1.			36		
							2.7
2007	DATE	ORBIT No.	FRAME	Nos	TIME	CO-ORDS OF	CENTRE
INCE LAUNCH)	(1975)	01011 110.	4	5	H: M: S	LATITUDE	LONGITUDE
2155	26 JUNE	2157	135	151	10: 32: 10	N59:54	E000:31
``			136	152	10: 32: 30	N 58:32	w 000:26
			166	184	Mark of Marketon State of State of State of		
2157	28 JUNE	2185	202	220	10:44:00	N28:33	61:500M
			178	209			
2160	1 20rx	2227	179	210	11:00:50	N59:53	moop: 38
	h	****	182	272	11:01:10		W007:36
			21114	542	11:02:50	N25:26	m010:23
			001	021			110(31)(0
2161	2 JULY	2241	041	061	11:09:30	N50: 11	W013:40
	1. 31111	2269	200	221	11:18:00	N50 157	W010:53
2163	4 JULY	2263	242	263		N58:34	won:51
			202	553	11: 18:20		W012:46
1			244	265	11: 10:30	01:F2N	w 0, 2, 46
	~	22.02	214	226	11:23:40	N59:56	mo12:22
2164	5 July	5583	218	250		N28:33	mo13:20
			539	251	11: 24:10	1430.53	0013;20
		226	012	031	13.26.10	N(-0, 01/-	E002:05
2172	13 arry	2394	050	035	13:26:10	N60:04	
	***************************************		014	010	11:26:40	N58:41	E001:07
		Section and advanced to the contract of the contract of	012	034		NS7:18	E000:12
1			016	035	10:27:30	NSS:54	M000:39
			054	036		N54:30	W001:27
	******		085	550	10:28:20	N23:06	W002:13
			019	076	10:28:40		MOOS:26
	•		057	677		420:13	w 003: 36
			155	174		N60.05	Econilia
2173	14 JULY	2408	156	175			E000:40
i			194	213	10:32:20	1428:45	M000: 19

,			•	-		•
DAY	DATE	ORBIT No.	FRAME Nos.		CO-ORDS D	
(SINCE CAUNCH)	(1975)		6 7	H: M: S	LATITUDE	LONGITUDE
2176	17 JULY	2450	075 104	10:50:50	N24:35	W007:10
•	"	"	076 105	10:51:10	N23:08	WOO7:55
4	4		077 106	10:51:40	NS1:43	0008:38
•	"		078 107	10:52:00	NSO: 19	81:6000
	, v		049 108		N48:54	w∞9:57
		**	002 035			
2179	20 JULY	2492	068 (0)	11:06:40	N58:46	008:50
**	"		069 102		N57:23	W009:45
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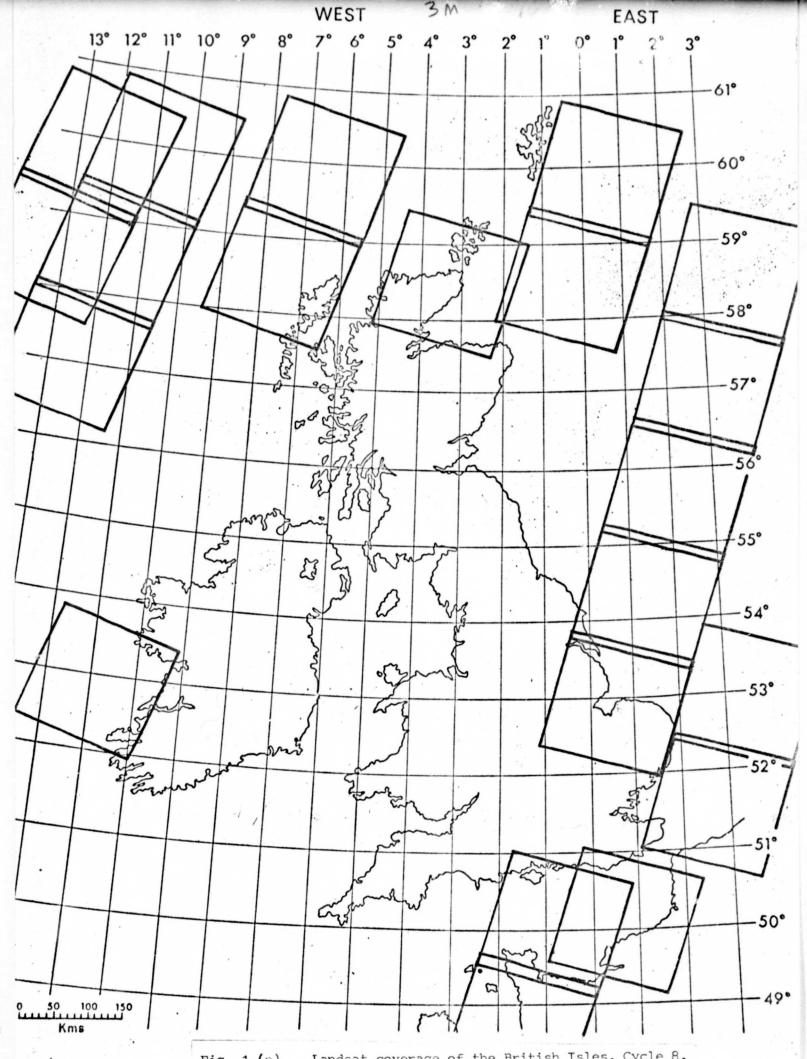


Fig. 1 (e) Landsat coverage of the British Isles, Cycle 8, 20 June - 7 July, 1975.

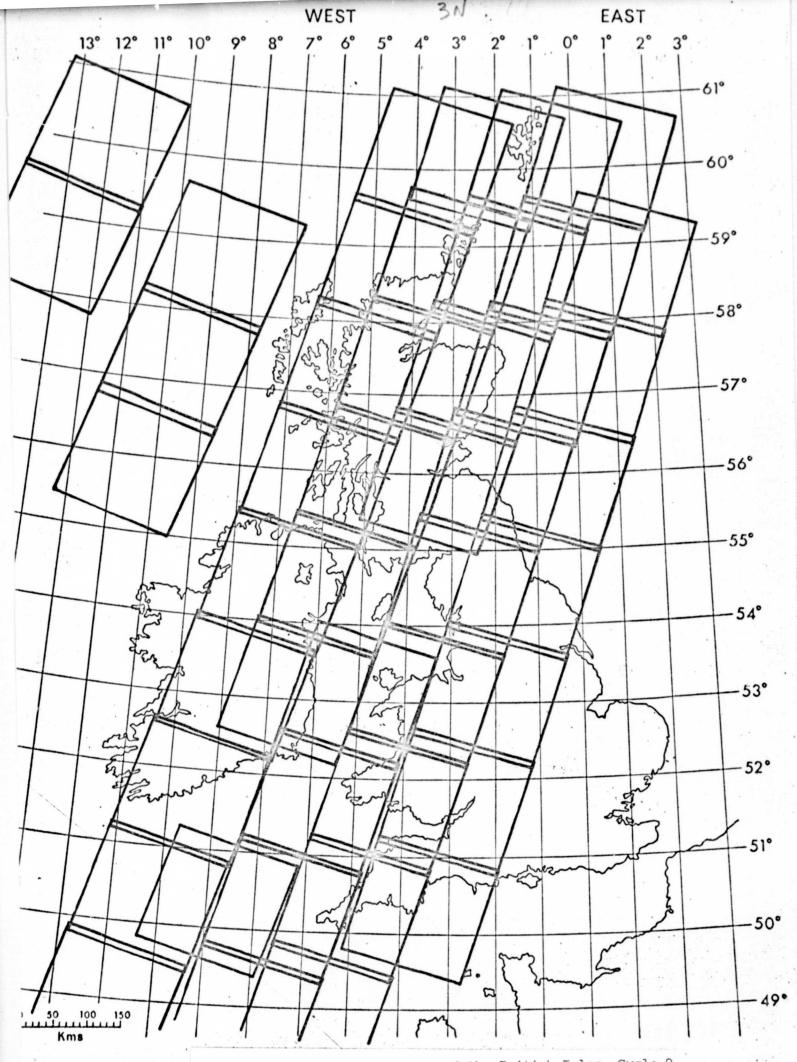


Fig. 1 (f): Landsat coverage of the British Isles, Cycle 9, 8 July - 25 July, 1975.

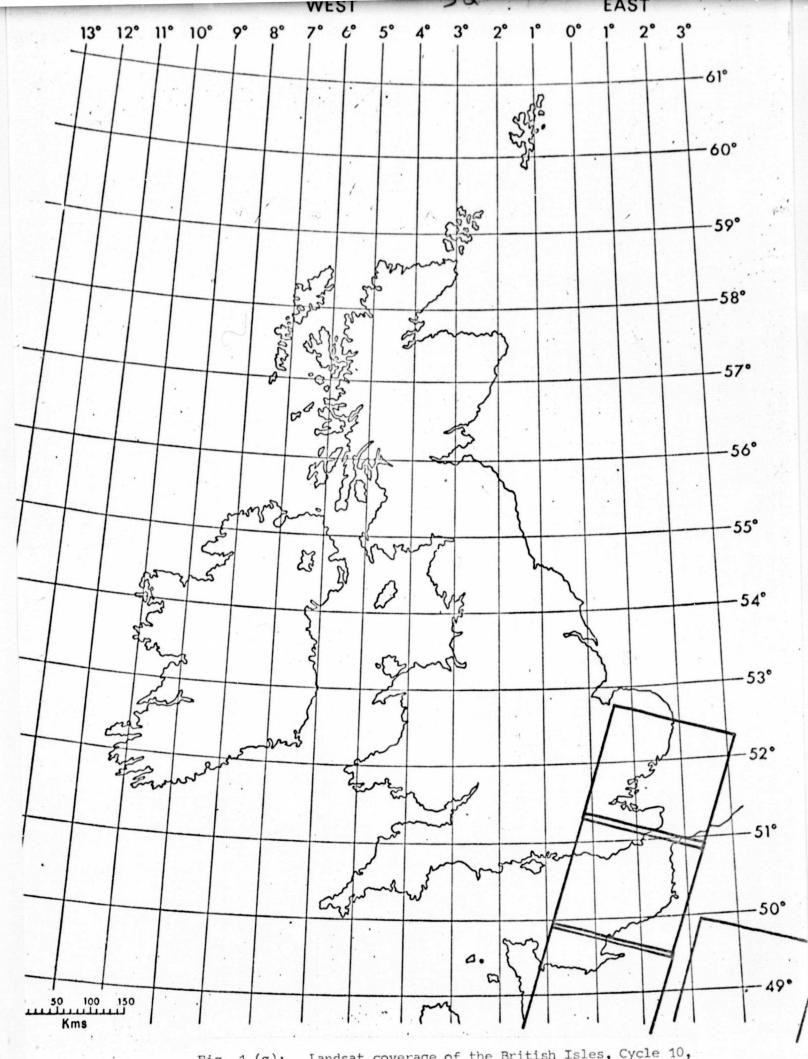


Fig. 1 (g): Landsat coverage of the British Isles, Cycle 10, 26 July - 12 August, 1975.

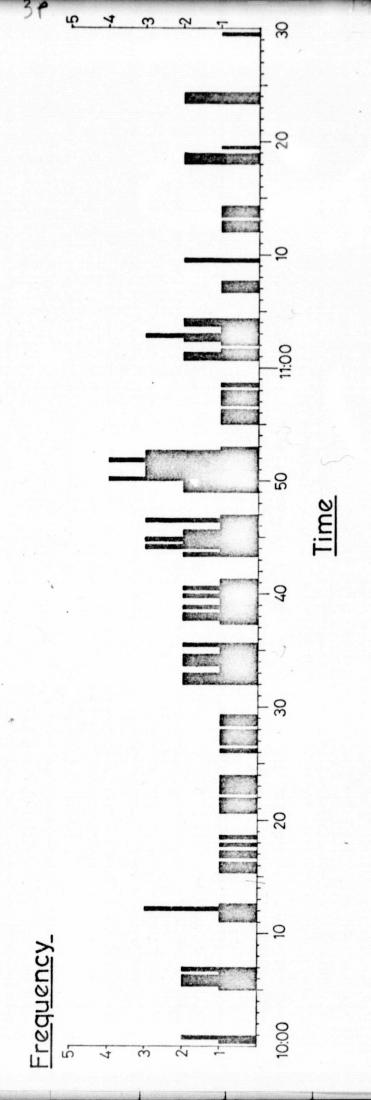


Fig.2 Distribution of the imagery through time

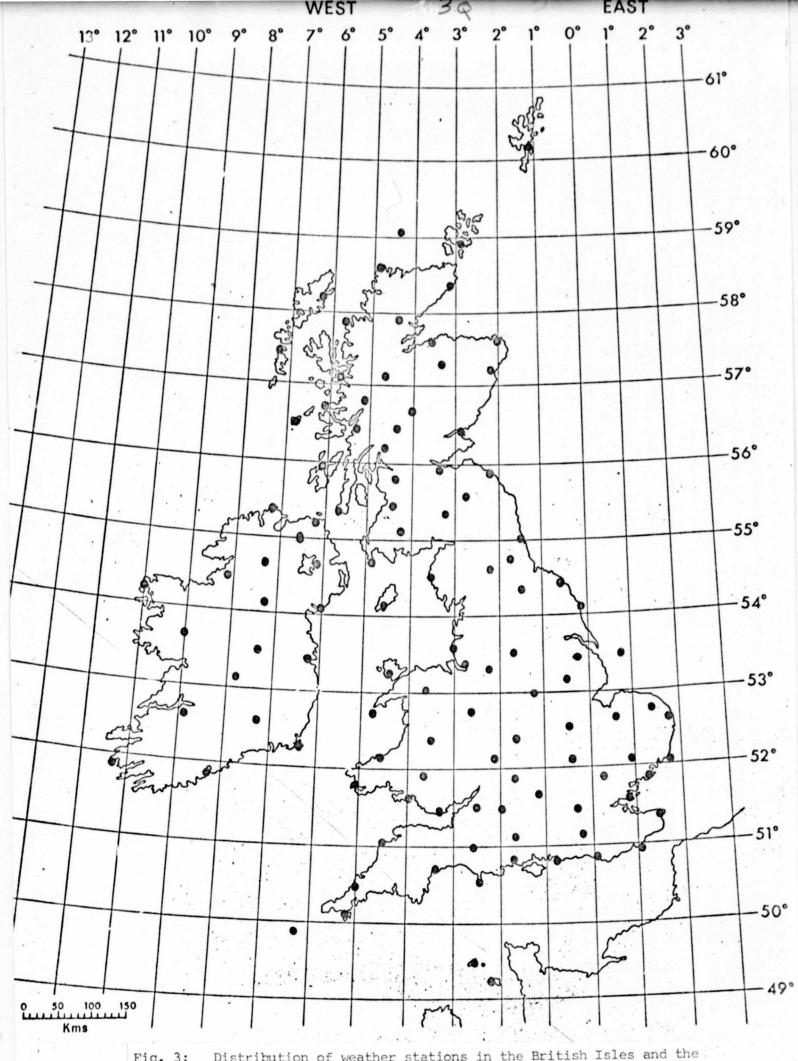


Fig. 3: Distribution of weather stations in the British Isles and the Republic of Ireland reporting hourly.

on the reasonable grounds that the Observer's lot is already a busy one, and that sporadic rearrangement of a schedule would be a source of confusion which might lead to loss of efficiency.

In fact, we are not unduly worried by the time differentials separating the two data gathering approaches. Cloud is usually rather slow to develop and/ or change, and, in reasonable populations of comparative statistics we might expect that the effects of observing non-contemporaneously by satellite and on the ground would be distributed about the mean-relationship. Possibly significant cloud character contrasts resulting from the relatively rapid operation of meteorological processes in knife-edge situations will be disallowed from our statistical comparisons by means to be decided in view of the scale of the problem when it is apparent. One suitable means might be the construction of envelope curves of bivariate scattergrams of satellite and conventional cloud estimates to indicate the more seriously affected relationships. The kinds of symoptic situations in which these might occur range from highly mobile weather systems bringing frontal cloud quickly across areas which were previously covered by little or no cloud, to static situations in which, for example, overnight radiation fog may be rapidly dispersed. Examples of such situations will be sought and illustrated in later reports.

Whilst our file of Landsat frames is being extended, we are giving detailed thought to the design of our techniques for image analysis, with particular reference to cloud type and area, and for the correlation of the results with conventional cloud observations. Since conventional methods of observing cloud characteristics are non-instrumental, there is a greater chance of observational variation from day to day, from observer to observer, and from place to place than with most meteorological parameters. The more important sources of variation associated with the methodology for observing clouds include the following:

(1) The location of the observing station in relation to surrounding relief features, buildings, trees, etc., which may affect the extent and shape of the visible bowl of the sky.

- (2) The variation of the radius of the cloud area assessed in conjunction with differences in the height of the cloud base.
- (3) The effect of special influences upon cloud type and cloud cover locally, e.g., hill ranges enhancing cloud by day and water bodies suppressing cloud growth in the morning.
- (4) The subjective judgement of the observer in the periodic assessment of cloud type, and cover, across a field of view in which perspective changes continuously from the vertical line of sight to the horizons.
- The advice given to the observer in his training programme.

  The British observer is advised to "give equal weight to the areas around the zenith and those at a lower angular elevation" (H.M.S.O. 1969). It is not easy to decide what such advice means in terms of relative areas; in practice, greater weight is almost certainly given to that (comparatively small) area overhead in which the relations between cloud elements and breaks in the cloud are most obvious.

It is to (1) and (2) above that we intend to address our attention in particular, believing that the other three would be difficult to investigate in any objective way. The first may be elucidated by circularising the reporting stations with a line-of-sight diagram to be completed in silhouette to indicate the distribution through 360° of skyline forms which result in angles of elevation or declination from the observing position. The second will entail inferences drawn from Table 3, which shows that the radius of the visible bowl of the sky (insofar as this may be defined in terms of the base of the clouds) is much wider for high clouds than for low.

The first routine analytical tasks which will be undertaken, therefore, involve the following comparisons:

(1) Conventional cloud observations and Landsat cloud estimates based on circular areas of a standard size centred on the

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12	687.5	1,484,805	343.6	370,975		229	164,710		171-6	92,518		137.2	59,103	68.1	1. REO
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8	4583	659,913	229.1	164,878		152.6	73,205		114-4	41,119		91.4	26,268	7-57	6010
n viewing of elevati	343.7	371,201	171.8	92,744	,	114-5	41,179		82.8	23,129	***	9-89	14,776	34.0	0000
is cloud areas seen from viewing for different angles of elevation of clouds $(kms.)$	286.5	257,779	143.2	64,405		95.4	28,596		71-5	16,062		57.2	10,261	28.4	(
oud areas seen different angle clouds (kms.)	229.2	164,978	114.5	41,219		76.3	18,301		57.2	10,280		7-2-7	6,567	22.7	
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station positions.

- (2) Conventional cloud observations and Landsat cloud estimates based on circular areas of different sizes depending on the height of the dominant cloud; and, if information about obstruction silhouettes is adequate and our results seem to warrant it, comparisons between.
- (3) Conventional cloud observations and Landsat cloud estimates based on station-specific sky areas of appropriate shapes.

## III ACCOMPLISHMENTS

There is little to report under this heading owing to the preliminary nature of our work to date. Although the first Landsat imagery were received early in August 1975, it was not possible to commence work upon the data until the beginning of October, which has left little time for progress to be made. However, it is clear that Landsat has already provided cloud information for the British Isles with certain very distinctive and potentially valuable characteristics. These include:

- (1) Breadth of cover. Conventional cloud observations from
  the British meteorological station network ar very largely
  overland observations. Landsat has provided some data for
  coastal waters which could not have been obtained from
  the surface. Additionally, of course, the Landsat views
  are spatially complete as distinct from the isolated pointsampling-views obtained from conventional meteorological
  stations on the ground.
- (2) Detail of cover. The highest resolution meteorological satellite data for the British Isles are within the range from c. 0.6 4.0 km. depending on waveband, time of day, and the operation of DMSP and Noaa satellites and associated reception facilities. Although the Landsat coverage is more restricted temporally, it is much more detailed in terms of resolution, bettering the meteorological satellite data by one or two orders of magnitude.

### IV. PROBLEMS

In the Introduction, reference was made to some of the difficulties which have impeded the progress of the investigation to this point in time, especially those which have necessitated some reappraising of the original study plan.

A related problem of a continuing nature is the uncertainty that Landsat will image any given area of the study region during a particular cycle. To date, the "on-off" pattern of behaviour has appeared essentially random. Coupled with the rather low frequency of coverage which has been achieved for most sub-regions rather serious difficulties have arisen with tasks we would have liked to have planned, but which are either labour or cost-intensive. For example, time-synchronised cloud photography from the ground at a number of locations might have provided a useful further check on comparisons between satellite and conventional surface cloud observation, and the use of instrumented aircraft from the Meteorological Flight and/or the time-synchronisation of weather radar observations organised by the Royal Radar Establishment could have yielded very valuable supporting information; those who would have been involved in such programmes needed a suitable assurance that their services would not have been provided in vain. Whether the advent of the Telespazio station in Italy will improve matters during the remaining weeks of the data gathering exercise (ending February 29th, 1976) remains to be seen. Some indication of the likelihood that this might be so would be appreciated.

Lastly, it may be repeated that, for in-house reasons, the study was not begin until early October 1975, coincidental with the opening of a new university session in Bristol.

#### V. DATA QUALITY AND DELIVERY

The quality of the data received has been dominantly fair or good, with the exception of a small proportion of transparencies which were heavily finger-marked.

Their timeliness has been poorer than expected. There has been a consistent delay of about four months from the date of imaging to the receipt of the imagery.

This is considerably longer than the delay experienced by clients with standing orders for images, a fact which has caused some embarrassment to the present Principal Investigator when questioned on Landsat data availability by scientific bodies and the media.

## VI. RECOMMENDATIONS AND CONCLUSIONS

The fragmentary nature of the Landsat coverage of the British Isles to data, coupled with the considerable uncertainty in advance that coverage might be obtained in specified areas during selected Landsat cycles, has seriously affected our hopes of achieving certain agreed goals and additional targets. If a full coverage through space and time, within the limits approved by NoAoSoAo is not possible, a planned coverage whose details would be known in advance, would be much more helpful than past experience. In large measure, our project in its final form will be dictated by the data we have received. For this reason, the feasibility of some tasks may only be clear when the last consignment of images has arrived. Clearly, this is scientifically unfortunate. Although we are hopeful that useful and interesting results will still emerge from our study, we regret that its original design and its final execution may have rather little in common.

# VII. REFERENCES

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